• CE Amplifier without by passed capacitor

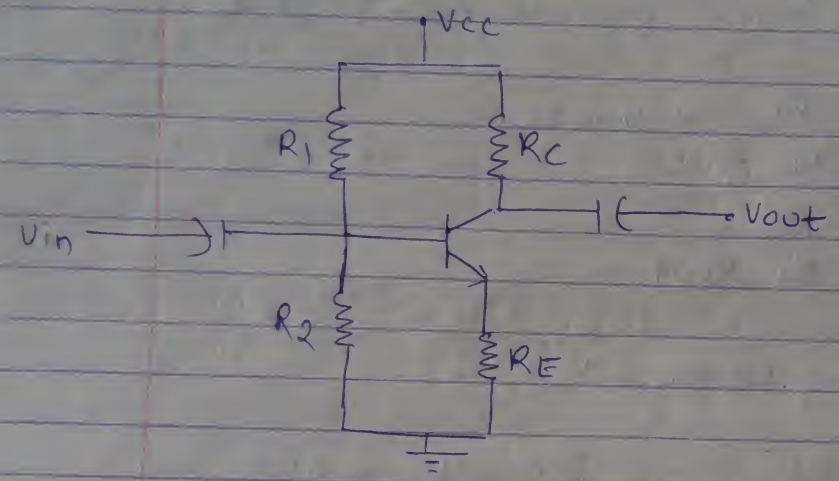


fig: CE amplifier ckt without bypassed capacitor (CE)

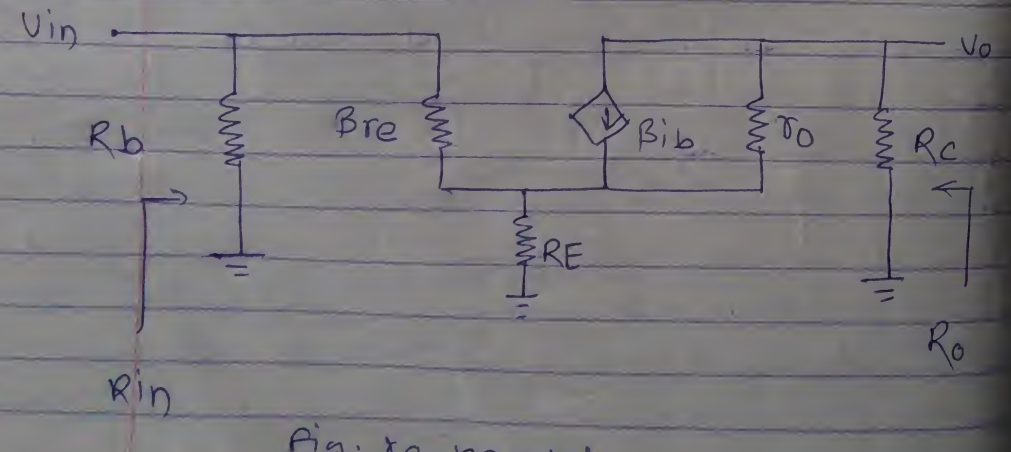


fig: re-model

finding Rin:

$$Rin = Rb // [\beta re + (\beta+1)RE]$$

$\beta >> 1$, $\beta + 1 = \beta$

$$Rin = Rb // (\beta re + \beta RE)$$
$$= Rb // \beta(re + RE) \quad [\because Rb \geq 10\beta re]$$
$$= \beta(re + RE)$$
$$= \beta RE$$

At open (ie RC not included) ro is max and RE is minimum

$$Roc = ro + RE$$
$$ro >> RE$$
$$Roc \simeq ro$$

Or,

$$Rout = Roc // RC$$
$$= ro // RC$$
$$\simeq RC \quad (ro >> RC \text{ at open})$$

finding AV;

Vib = βreib + (β+1) ibRE

$\frac{Vib}{ib} = \beta re + (\beta+1)RE$

Rib = βre + (β+1) RE

Vout is Rout

$= -i_c R_{out}$

$= -\beta i_b [R_c // (r_o + R_E)]$

$V_{in} = V_b = R_{ib} i_b \quad \left(\because R_{ib} = \frac{V_{ib}}{i_b} \right)$

$A_V = \frac{V_o}{V_{in}} = \frac{-\beta i_b [R_c // (r_o + R_E)]}{i_b [\beta r_e + (\beta + 1) R_E]}$

$= \frac{-\beta i_b [R_c // (r_o + R_E)]}{i_b [\beta r_e + \beta R_E]}$

$= \frac{-\beta [R_c // (r_o + R_E)]}{\beta r_e + \beta R_E}$

$= \frac{-[R_c // (r_o + R_E)]}{r_e + R_E}$

$= \frac{-[R_c // r_o]}{r_e + R_E}$

$= \frac{-R_c}{r_e + R_E}$

$A_i = \frac{i_o}{i_{in}} = \frac{i_o}{i_b} * \frac{i_b}{i_{in}}$

$= -\beta \frac{R_b}{R_b + R_{ib}}$

$= -\beta$

Comparison between the common emitter amplifier ckt with RE and without RE and excluding R_S and R_c

From the analysis of CE amplifier ckt with and without RE and with and without R_S and R_L we observed that including an emitter resistor RE in the amplifier ckt results in the following characteristics:

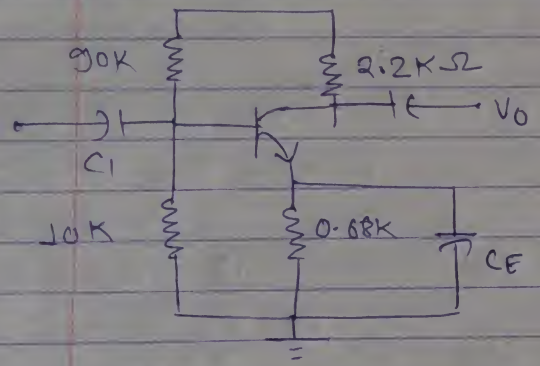
1) R_{ib} is increased by the factor $(\beta+1)R_E$
2) A_{vo} is reduced from $-\frac{R_c // r_o}{r_e}$ to $-\frac{R_c // r_o}{r_e + R_E}$ or it is reduced from $\frac{R_c}{r_e}$ to $\frac{R_c}{R_E + r_e}$

3) It means the frequency response of the ckt significantly increased (improved

Numerical: 1

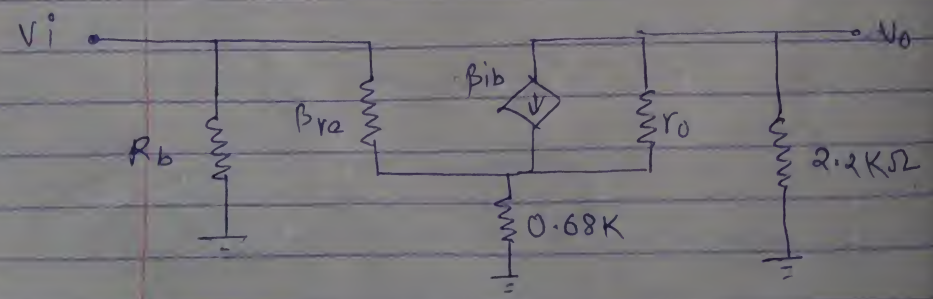
for the N/W of figure below (with CE unbypa-ssed), determine (using approximate approximation)

a. r_e b. Z_i c. Z_o and d. A_V



Soln;

preparing re-model



$\{BR_E > 10R_2\}$

Now,

$R_b = 90 // 10$

$= \frac{90 * 10}{90 + 10}$

$= \frac{900}{100}$

$= 9K\Omega$

$V_B = \frac{R_2}{R_1 + R_2} * 16$

$= \frac{10}{10 + 90} * 16$

$= 1.6V$

$V_E = V_B - V_{BE} = (1.6V - 0.7V) = 0.9V$

So, $i_E = \frac{V_E}{R_E} = \frac{0.9V}{0.68K} = 1.32mA$

(a) $r_e = \frac{26mV}{1.32mA} = 19.6\Omega$

(b) $Z_{in} \simeq R_{in}$ [testing condn: $r_o \geq 10R_E$ or, $r_o \geq 10(R_E + r_E)$]

$R_b = R_1 // R_2 = 9K\Omega$

$Z_b = \beta R_E$

$Z_{in} = 9K\Omega // \beta R_E$

$= 9K\Omega // 142.80$

$= 8.466404K\Omega$

(c) $Z_{out} = R_C$

$= 2.2K\Omega$

(d) $A_V = \frac{-R_C}{R_E + r_o}$

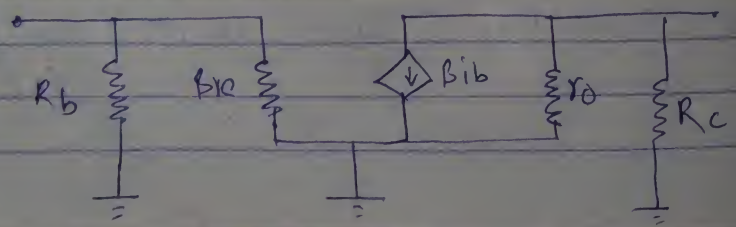
$= \frac{-R_C}{R_E}$

$= \frac{-2.2}{0.68}$

$= -3.2350$

Also Dopeat with CF connected

(e) Vin



(a) $Z_{in} = R_b // R_{ib}$

~~$= (R_1 // R_2) //$~~

since $R_b \geq 10\beta r_e$

$R_{in} = \beta r_e$

$= 210 * 30.64$

$=$

$i_b = \frac{V_B - V_{BE}}{R_2}$

Emitter follower Amplifier

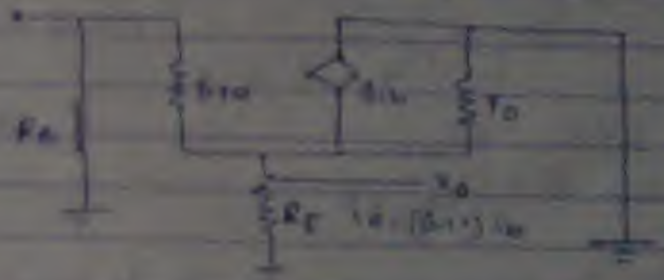
Fig: Emitter follower circuit

- Since collector is directly connected to the collector terminal of the transistor so it is known as common collector amplifier.
- Output is taken from the emitter terminal of the transistor so it is also known as emitter follower.
- It is slightly less than unity because of the drop of V_{BE} junction. But $A_V \approx 1$ (practical)
- Input is applied in base which is in same phase with the input signal V_s. It is used in many stages because it has high input impedance and low output impedance.
- It is also used as buffer amplifier.
- Collector is connected to the ground $\rightarrow$ DC connection collector

Applications:

- Used for impedance matching purpose i.e. to provide high impedance at the I/P and low at O/P. So high Z_i and low Z_o is used as buffer or isolating ckt.

AC Analysis



$Z_i = R_B \| Z_b$

$Z_b = \beta(r_e + R_E)$ [$\because R_E \gg r_e$]

$Z_b = \beta R_E$

Since $R_E = r_e$

$Z_b = \beta R_E$

And o/p impedence;

$$i_b = \frac{V_{ib}}{R_{ib}}$$

$$\text{or, } (\beta+1) i_b = (\beta+1) \frac{V_{ib}}{R_{ib}}$$

$$\text{or, } i_e = (\beta+1) \frac{V_i}{Z_b} \quad [R_{ib} = Z_b]$$

or,

$$i_e = \frac{(\beta+1) V_i}{\beta r_e + (\beta+1) R_E}$$

or,

$$i_e = \frac{V_i}{r_e + R_E}$$

To determine Z_o, V_i is set to zero.

And,

$$Z_o = R_E \,//\, \beta r_e$$

$$Z_o = \beta r_e \quad [R_E >> \beta r_e]$$

Now applying voltage divider rule,

$$V_o = \frac{R_E}{R_E + \beta r_e} \cdot V_i$$

$$\text{or, } \frac{V_o}{V_i} = \frac{R_E}{R_E + \beta r_e}$$

$$\therefore A_V = \frac{R_E}{R_E + \beta r_e} \simeq 1$$

Alternative method for A_V

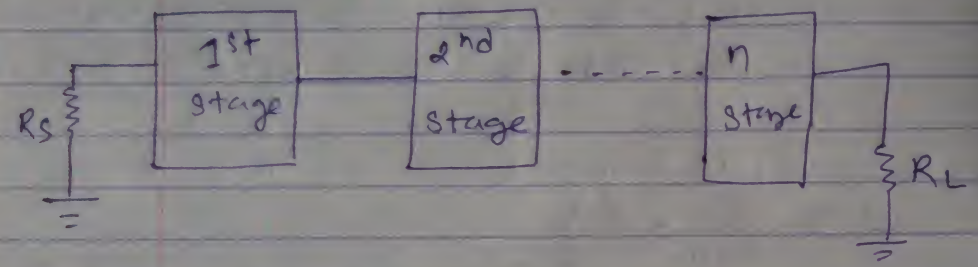
$$V_o = i_e \cdot R_E$$

$$= (\beta+1) i_b \cdot R_E$$

$$V_{in} = V_{ib} = \beta r_e \cdot i_b + (\beta+1) i_b R_E$$

$$\therefore A_V = \frac{V_o}{V_{in}} = \frac{\beta R_C}{Z_b}$$

Multistage Amplifiers:



Overall voltage gain = V_L/V_S

Overall voltage gain = $A_1 * A_2 * A_3 \cdots A_{n-1} * A_n$

Overall voltage gain is equal to the product of the individual gain of the stages of amplifier.

$A < A_1 * A_2 * A_3 \cdots A_n$ [Due to loading effect or shunting effect]

practical;

$20\log_{10}(A) = 20\log_{10}(A_1) + 20\log_{10}(A_2) + \cdots 20\log_{10}(A_n)$

Overall voltage gain in n-stage Amplifier:

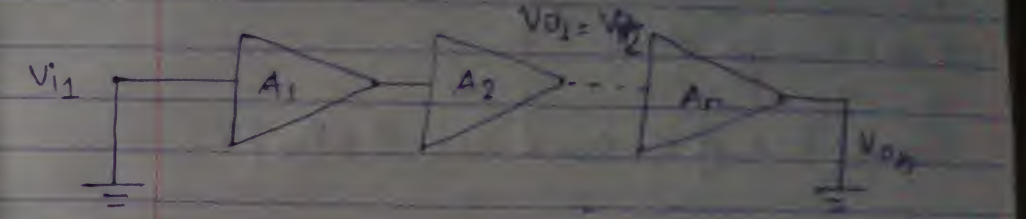


fig: n-amplifier stages connected in cascaded ie the o/p of one stage is the i/p to the next stage

By Definition;

$V_{o1} = A_1 V_{i1}$ — (i)

Also,

$V_{o2} = A_2 V_{i2} = A_2 V_{o1}$ — (ii) [$V_{i2} = V_{o1}$]

Now substituting eqn (i) in to (ii)

$V_{o2} = A_2 \cdot A_1 \cdot V_{i1}$ — (iii)

Similarly;

$V_{o3} = A_3 \cdot V_{i3} = A_3 V_{o2}$ [$V_{i3} = V_{o2}$]

$V_{o_2} = A_2 \cdot A_1 \cdot A_1 V_{i_1}$

Hence continuing in this manner we eventually find.

$V_{in} = V_i = (A_n \cdot A_{n-1} \cdots A_2 A_1) V_{i_1}$

$\Rightarrow \frac{V_{in}}{V_{i_1}} = A_n * A_{n-1} \cdots A_2 * A_1 \quad — (IV)$

So eqn (IV) is overall voltage gain of the n-cascade system, which is equal to the product of the gain of n-individual system.

Note 1:
If one of the amplifier stage is (-ve) the overall voltage gain is 180° out of phase

Note 2:
if n=odd, then no effect
n=even

This implies overall voltage gain in dB:

$$20\log_{10}\left(\frac{V_{on}}{V_{I_1}}\right) = 20\log_{10}\left[A_n * A_{n-1} * \cdots A_2 A_1\right]$$

Note 3:
Effect of source resistance (R_S) and load resistance (R_L) on the overall voltage gain:

R_S causes the usual voltage division to take place at the input to the 1st stage and R_L causes the voltage division to occur between R_L and the output resistance of last stage.

Under these circumstances the overall voltage gain of n-cascated system with R_S and R_L will be;

$$\frac{V_L}{V_S} = \left(\frac{R_{in_1}}{R_S + R_{in_1}}\right) * A_n * A_{n-1} \cdots A_2 * A_1 * \left(\frac{R_L}{R_L + R_{on}}\right)$$

Darrington pair Amplifier

When the collector of two BJT's are tied together the emitter 1st transistor is directly coupled to the base of the 2nd transistor such configuration is called Darlington Pair.

Let β_1 to β_2 be the dc β values of transistor 1 and 2 respectively.

We know,

$I_{C1} = \beta I_{B1}$

$I_{E2} = (\beta+1) I_{B1}$

From fig

$I_{E1} = I_{B2}$

$\therefore I_{C2} = \beta_2 I_{B2}$

$= \beta_2 (\beta_1+1) I_{B1}$

Since $I_C = I_{C1} + I_{C2}$

$= \beta_1 I_{B1} + \beta_2 (\beta_1+1) I_{B1}$

$= I_{B1} [\beta_1 + \beta_2 (\beta_1+1)]$

$= (\beta_1 + \beta_2) I_{B1} + \beta_1 \beta_2 I_{B1}$

And $I_B = I_{B1}$

So,

$I_C = (\beta_1+\beta_2) I_B + \beta_1 \beta_2 I_B$

$\Rightarrow \frac{I_C}{I_B} = \beta_1 + \beta_2 + \beta_1 \beta_2$

$\therefore \beta_{DP} = \beta_1 + \beta_2 + \beta_1 \beta_2$

Since,

$\beta_1 \beta_2 \gg \beta_1 + \beta_2$

$\beta_{DP} = \beta_1 \beta_2$

If

$\beta_1 = \beta_2 = \beta$

Then $\beta_{DP} = \beta^2$

Hence the Darling pair is also called superBeta.

Small-signal ...ysis of Darlington pair
To determine th...ffective small I/P
resistance from B... F function.

$$r_{e_2} = \frac{26mV}{I_{E_2}}$$

looking into the ...se of transistor Q_2

$$r_{in(Base)_2} = \ldots_2$$

$$r_{e_1} = \frac{26mV}{I_{e_1}} \qquad I_{E_2} = (\beta_2 + 1) I_{B_2}$$

or $I_{E_2} = (\beta_2 + 1) I_{E_1}$

$$I_{E_1} = \frac{I_{E_2}}{\beta_2} \qquad \text{or} \quad \frac{I_{E_2}}{I_{E_1}} = \beta_2$$

$$r_{e_1} = \beta_2 \left(\frac{26mV}{I_{E_2}} \right.$$

Now,

~~$r_{in\,Dp} = \beta_1 r_e$~~ $= r_{E2}$

~~$: \beta_1 \times$~~ $\left(\frac{26mV}{I_{E_2}} \right)$

$r_{in_{DD}} = \beta_1 (r_{ei} + \ldots_{n\,Base_2})$

~~$: \beta_1 (r$~~

It is the ...ective resistance
looking into the b... of Q_1 accross the

effective small signal input resistance

composite base to emitter terminal.
$r_{in\,DP}$ is the effective small signal resistance of
effect of Darlington pair

$$r_{in\,Dp} = \beta_1 (r_{e_1} + \beta_2 r_{e_2})$$

$$= \beta_1 (\beta_2 r_{e_2} + \beta_2 r_{e_2})$$

$$= 2\beta_1 \beta_2 r_e$$

$$r_{e(Dp)} = \frac{r_{in\,Dp}}{\beta_{Dp}}$$

When a load is connected at the output of the Darlington pair configuration then the total input resistance to the follower circuit is,

$$r_{in} = r_{in\,DP} + \beta_{DP} R_L$$